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DECLARATION

I, Yutaka Horii, c/o Fukami Patent Office, of Mitsui Sumitomo Bank Minamimorimachi Building, 1-29, Minamimorimachi 2-chome, Kita-ku, Osaka-shi, Osaka, Japan, declare:

that I know well both the Japanese and English languages;

that to the best of my knowledge and belief the English translation attached hereto is a true and correct translation of Japanese Patent Application No. 2000-102088, filed April 4, 2000;

that all statements made of my own knowledge are true;

that all statements made on information and belief are believed to be true; and

that the statements are made with the knowledge that willful false statements and the like are punishable by fine or imprisonment, or both, under 18 USC 1001.

Dated: June 22, 2004

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[Title of the Invention] Optical Recording Medium, and Method and Apparatus of Reproducing Optical Recorded Information

[Claims for Patent]

[Claim 1] An optical recording medium comprising, on a substrate, a region having information recorded at least in a depth direction of a plane direction and depth direction of said substrate, and a region having information recorded in the plane direction of said substrate.

[Claim 2] An optical recording medium comprising, on a substrate, a region having information recorded by at least a depth of a pit of a presence/absence, a length, a width, a position, and a depth of a pit, and a region having information recorded by at least one of the presence/absence, the length, the width, and the position of a pit.

[Claim 3] The optical recording medium according to claim 2, wherein the region has information recorded in the depth direction of pits having at least two different depths on said substrate.

[Claim 4] The optical recording medium according to claim 3, wherein a tangential push-pull signal differing in polarity is obtained from said pits having two different depths in the region having information recorded in the depth direction of said pits having at least two different depths.

[Claim 5] The optical recording medium according to claim 3 or 4, wherein pits having at least two different depths (D2, D2) are set to satisfy

$\lambda/8n < D1 < \lambda/4n$ and $\lambda/4n < D2 < 3\lambda/8n$

where λ is a wavelength of light used in reproduction, and n is a refractive index of said substrate in the region having information recorded in the depth direction of said pits having at least two different depths.

[Claim 6] The optical recording medium according to any of claims 1-5, wherein additional information is recorded in at least the depth direction in the region having information recorded in at least the depth direction of the plane direction and

depth direction of said substrate.

[Claim 7] The optical recording medium according to claim 6, wherein main information is recorded in the region having information recorded in the plane direction of said substrate.

[Claim 8] The optical recording medium according to claim 6 or 7, wherein said additional information includes information inhibited of being copied into another recording medium.

[Claim 9] The optical recording medium according to claim 6 or 7, wherein said additional information includes information required for reproduction of said main information such as a cancel key of scrambling or encryption of said main information.

[Claim 10] The optical recording medium according to claim 6 or 7, wherein said additional information includes information unique to said optical recording medium such as identification (ID) information of said optical recording medium.

[Claim 11] The optical recording medium according to any of claims 1-5, wherein the presence of pits of different depths itself is the identification information of said optical recording medium in the region having information recorded in at least the depth direction of the plane direction and depth direction of said substrate.

[Claim 12] A reproduction method of optical recorded information, wherein recorded information is reproduced based on a polarity of a tangential push-pull signal obtained from pits having at least two different depths in a region recorded with information by said pits having at least two different depths on an optical recording medium.

[Claim 13] A reproduction method of optical recorded information, wherein recorded data is reproduced based on a combination of a signal according to a quantity of reflected light obtained from pits having at least two different depths and a polarity of a tangential push-pull signal obtained from said pits in a region having information recorded in said pits having at least two different depths on an optical recording medium.

[Claim 14] A reproduction method of optical recorded information according

to claim 12 or 13, wherein recorded data is reproduced from a signal according to the quantity of reflected light at a region having information recorded by at least one of a presence/absence, length, width, and position of a pit on said optical recording medium.

[Claim 15] A reproduction apparatus of optical recorded information, wherein recorded data is reproduced based on a polarity of a tangential push-pull signal obtained from pits having at least two different depths in a region having information recorded by said pits having at least two different depths on an optical recording medium.

[Claim 16] The reproduction apparatus of optical recorded information, wherein recorded data is reproduced based on a combination of a signal according to a quantity of reflected light obtained from pits having two different depths and a polarity of a tangential push-pull signal obtained from said pits at a region having information recorded by said pits having at least two different depths on an optical recording medium.

[Claim 17] The reproduction apparatus of optical recorded information according to claim 15 or 16, wherein recorded information is reproduced from a signal according to the quantity of reflected light at a region having information recorded by at least one of a presence/absence, length, width, and position of a pit on said optical recording medium.

[Claim 18] An identification method of an optical recording medium including a region having information recorded in a depth direction by pits of different depths on a substrate, wherein the presence of pits of different depths itself is unique identification information, and said unique identification information is identified based on a polarity of a tangential push-pull signal obtained from said pits.

[Claim 19] An identification apparatus of an optical recording medium, wherein the presence of pits of different depths itself is unique identification information, and said unique identification information is identified based on a polarity of a tangential push-pull signal obtained from said pits, in an identification method of optical recorded information including a region having information recorded in a depth direction by pits

of different depths on a substrate.

[Claim 20] A recordable optical recording medium comprising, on a substrate, a region having information recorded at least in a depth direction of a plane direction and depth direction of said substrate, and a region having information recorded in the plane direction of said substrate.

[Claim 21] A recordable optical recording medium comprising, on a substrate, a region having information recorded by at least a depth of a pit of a presence/absence, a length, a width, a position, and a depth of a pit, and a region having information recorded by at least one of the presence/absence, the length, the width, and the position of a pit.

[Claim 22] The recordable optical recording medium according to claim 21, wherein the region has information recorded in the depth direction of pits having at least two different depths on said substrate.

[Claim 23] The recordable optical recording medium according to claim 22, wherein a tangential push-pull signal differing in polarity is obtained from said pits having two different depths in the region having information recorded in the depth direction of said pits having at least two different depths.

[Claim 24] The recordable optical recording medium according to claim 22 or 23, wherein pits having at least two different depths (D2, D2) are set to satisfy

$\lambda/8n < D1 < \lambda/4n$ and $\lambda/4n < D2 < 3\lambda/8n$

where λ is a wavelength of light used in reproduction, and n is a refractive index of said substrate in the region having information recorded in the depth direction of said pits having at least two different depths.

[Claim 25] The recordable optical recording medium according to any of claims 20-24, wherein additional information is recorded in at least the depth direction in the region having information recorded in at least the depth direction of the plane direction and depth direction of said substrate.

[Claim 26] The recordable optical recording medium according to claim 25,

wherein main information is recorded in the region having information recorded in the plane direction of said substrate.

[Claim 27] The optical recording medium according to claim 25 or 26, wherein said additional information includes information inhibited of being copied into another recording medium.

[Claim 28] The optical recording medium according to claim 25 or 26, wherein said additional information includes information required for reproduction of said main information such as a cancel key of scrambling or encryption of said main information.

[Claim 29] The optical recording medium according to claim 25 or 26, wherein said additional information includes information unique to said optical recording medium such as identification (ID) information of said optical recording medium.

[Claim 30] A reproduction method of recordable optical recorded information, wherein recorded information is reproduced based on a polarity of at least a tangential push-pull signal obtained from pits having at least two different depths in a region having information recorded by said pits having at least two different depths on an optical recording medium, and recorded information is reproduced from a signal based on at least a quantity of reflected light at a region having information recorded by a mark.

[Claim 31] A reproduction apparatus of recordable optical recorded information, wherein recorded information is reproduced based on a polarity of at least a tangential push-pull signal obtained from pits having at least two different depths in a region having information recorded by said pits having at least two different depths on an optical recording medium, and recorded information is reproduced from a signal based on at least a quantity of reflected light at a region having information recorded by a mark.

[Detailed Description of the Invention]

[Technical Field to Which the Invention Belongs]

The present invention relates to an optical recording medium, and a reproduction

method and reproduction apparatus of optical recorded information, and to an optical recording medium including a region having information recorded in at least a depth direction of a substrate and a region having information recorded in a plane direction of the substrate, and a reproduction method and reproduction apparatus of optical recorded information recorded on the optical recording medium.

Additionally, the present invention relates to a recordable optical recording medium including a region having information recorded in at least a depth direction of a substrate and a region that can have information recorded in a plane direction of the substrate, and a reproduction method and reproduction apparatus of information recorded information recorded on the optical recording medium.

[Conventional Art]

A conventional optical disk has information binarized and recorded corresponding to the presence/absence, the length, the width or the position of pits and marks. In a disk dedicated to reproduction (ROM disk), information is recorded by providing holes (pits) on a substrate. In recordable disks such as a phase change disk, magneto-optical disk, organic dye disk and the like, recording marks are provided at the recording layer on the substrate to have information recorded.

Information is transposed to the absence/presence, the length, the width, or the position in the substrate plane of pits and marks to be recorded. In other words, information is recorded in the dimension of the plane direction of the substrate using pits or marks. The string of pits or marks is arranged concentrically or spirally on a circular substrate to form a track. The light beam follows this track to scan the string of pits or marks, taking advantage of the change in the quantity of reflected light or rotation of the plane of polarization of light to reproduce information.

The pit string or mark string arranged concentrically or spirally is generally assigned an address sequentially from the inner circumference. The region with the smaller address constitutes the region generally referred to as "lead-in". Information unique to the disk is written in this lead-in. Information required for the drive, the

player, or the recorder to record information, or reproduce information from the disks are provided.

Information unique to the disk includes, for example, the disk type (ROM, R, RW, RAM, or the like), the rotation speed and linear velocity for recording and reproduction, the laser power during recording, the address information of the region that can be used by the user, a cancel key of the scrambling of contents, and the like. The descramble key is the key used in scrambling the contents. The scramble cannot be canceled without this key. In other words, the cancel key is indispensable to reproduce scrambled contents.

In accordance with the higher density and higher level of functions of disks, the trend is to increase the amount of information written in the lead-in.

A conventional optical recording medium and a reproduction method and apparatus of optical recorded information will be described in detail hereinafter based on first to third conventional examples shown in Figs. 6-13.

Figs. 6-10 correspond to the first conventional example, wherein Fig. 6 is a schematic diagram of the arrangement of pits recorded on a ROM disk (disk dedicated to reproduction). A pit string 33 of a plurality of pits 32 are formed spirally on the plane of a substrate 31, whereby information is recorded.

Fig. 7 is a schematic diagram of pit string 33 formed spirally in the conventional ROM disk of Fig. 6, illustrated in a linear version from the inner circumference to the outer circumference of substrate 31. The lead-in is provided at the inner circumferential side, and then the user region is provided.

When the ID (identification information) of the ROM disk, the address information of the user region, and the information written in the user region are scrambled or encrypted, the scramble key or encryption key thereof is recorded therein.

Main information such as video and audio data is recorded in the user region. When the contents thereof become the subject of copyright protection, the main information will be scrambled or encrypted.

In Fig. 7, (a) represents the arrangement of pits 32 from the inner circumference to the outer circumference of substrate 31.

In Fig. 7, (b) represents a schematic cross section of substrate 31, illustrating holes corresponding to pits 32 formed in a concave manner. Pit 32 is formed with a constant depth.

In Fig. 7, (c) represents an RF signal obtained when pit string 33 is reproduced. In Fig. 7, (d) represents a tangential push-pull signal (TPP signal) obtained in reproducing pit string 33.

The RF signal and TPP signal will be described based on Figs. 8-10.

Fig. 8 (A) is a schematic diagram representing pit 32 scanned with a beam spot 34. Fig. 8 (B) represents the manner of reflected light 35 guided to a detector 37 formed of photoreceptor elements 36a and 36b divided into two regions A and B. The RF signal and TPP signal are obtained by the following equation using respective outputs of the two photoreceptor elements A and B.

$RF = A + B$

$TPP = A - B$

Fig. 9 represents the relationship between the depth of pit 32 and the amplitudes of the RF signal and tangential push-pull signal (TPP signal).

The horizontal axis corresponds to the depth of pit 32, based on the wavelength (λ) of light employed in reproduction, and n is the refractive index of substrate 31. In the present embodiment, an optical system based on a wavelength of 650 nm and 0.65 NA is employed to carry out experiments on a transparent substrate disk having the thickness of 0.6 mm and a refractive index of approximately 1.5.

The amplitude of the RF signal is maximum when the pit depth is $\lambda/4n$ (108 nm). The vertical axis at the right side in Fig. 9 is standardized with this value as 1.

The amplitude of the TPP signal is maximum when the pit depth is $\lambda/8n$ (54 nm), and the vertical axis at the left side in Fig. 9 is standardized with this value as 1.

The TPP signal has its polarity inverted at the boundary of pit length $\lambda/4n$. To

represent the same, the TPP signal takes a negative value in the region of $\lambda/4n <$ pit depth $< \lambda/2n$ (216 nm) in Fig. 9.

The inversion of the polarity of the TPP signal will be described hereinafter.

Consider a pit 32a of a depth D1 (86 nm) and a pit 32b of a depth D2 (130 nm) shown in Fig. 9.

Fig. 10 represents the RF signal and TPP signal when a pit string 33 of such depths is reproduced. In Fig. 10, the optical beam moves from left to right.

The RF signal has the reflected light reduced as compared to a non-pit region in either pit of the two depths.

The TPP signal exhibits a pulse in the positive direction (upwards in Fig. 10) at the leading edge of pit 32a, and then exhibits a pulse in the negative direction (downwards in Fig. 10) at the trailing edge of pit 32a, for pits of depth D1. As to the pits of depth D2, a pulse is exhibited in the negative direction (downwards in Fig. 10) at the leading edge of pit 32b, and then a pulse in the positive direction (upwards in Fig. 10) is exhibited at the trailing edge of pit 32b. This phenomenon is referred to as the inversion of the polarity of the TPP signal. In Fig. 9, the polarity of the TPP signal obtained at pit 32a of depth D1 is represented as positive, and the opposite polarity of the TPP signal is represented as negative.

In Fig. 7(c), the quantity of reflected light of the light beam is small at the pit portion and large at the non-pit portion. Therefore, the RF signal as shown in Fig. 7 (c) is obtained. In Fig. 7 (d), the TPP signal has the same polarity for all the pits since the pits are formed with a constant depth.

Fig. 11 includes a schematic diagram of a configuration of a mark string on a recordable disk in accordance with the second conventional example, and waveforms of signals obtained in reproducing information recorded on a recordable disk.

Fig. 11 (a) is a schematic diagram of a mark string 46 formed of a number of marks 45 written on the plane of a recordable disk, illustrated in a linear version from the inner circumference to the outer circumference of substrate 41. A guide groove of

the light beam that is generally referred to as a groove 44 is provided in the recordable disk. The light beam follows this groove 44 or the land between such grooves to write a mark 45. Mark 45 can be written in either or both of the groove and land. The example of Fig. 11 represents an example in which mark 45 is written in groove 44.

Fig. 11 (b) schematically shows a cross section of the disk. The mark portion does not have a hole formed as for pits. The reflectance of light differs between a mark portion 45 and a non-mark portion in a recording layer provided on substrate 41.

Fig. 11 (c) represents an RF signal obtained in reproducing mark string 46, corresponding to the case where the quantity of reflected light in the mark portion is smaller than that of the non-mark portion.

Fig. 11 (d) represents a tangential push-pull signal (TPP signal) obtained in reproducing mark string 46. Since mark 45 is formed having a constant depth on groove 44, the TPP signal has the same polarity in all marks 45.

The third conventional example will be described with reference to Figs. 12 and 13.

Fig. 12 is a schematic diagram showing an unrecorded status of a recordable disk employing a phase change recording layer.

A groove 54 which is a guide groove is formed spirally on the plane of a substrate 51. Information is recorded in the form of marks 55 along the guide groove. Pits 52 constitute a portion of groove 54. Information that should not be rewritten is recorded by pits 52.

Fig. 13 includes a schematic diagram of the configuration of a mark string and pit string of the recordable disk of Fig. 12, and waveforms of signals obtained by reproduction from the recordable disk.

Fig. 13 (a) schematically shows the manner of marks 55 recorded on a spiral groove 54 of the recordable disk, illustrated in a linear version from the inner circumference to the outer circumference of substrate 51.

Mark 55 is written in either or both of the groove and land. Fig. 13

corresponds to the case where marks 55 are written in groove 54. The lead-in is provided at the inner circumferential side, and then a user region is provided. The ID (identification information) of the disk, the address information of the user region, as well as a scramble key or encryption key when the information in the user region is scrambled or encrypted are written in the lead-in region.

Main information such as video and audio is recorded in the user region. The main information is scrambled or encrypted when the contents are the subject of copyright protection.

Fig. 13 (a) represents the arrangement of marks 55 and pits 52 from the inner circumference to the outer circumference of substrate 51.

Fig. 13 (b) schematically represents the cross section of the disk, having holes provided in a concave manner at the pit portion. Pit 52 is formed with a constant depth. Mark portion 55 does not have a hole formed as in pit 52, and has different reflectance of light between a mark portion and a non-mark portion in a recording layer provided on the substrate. Although the depth of groove 54 and pit 52 may be identical, it is preferable for a shallow groove 54 for the purpose of improving the signal quality of mark 55. If the signal quality of pit 52 is to be improved, a depth of approximately $\lambda/4n$ is preferable. Therefore, it is preferable to form the pit deeper than the groove. Here, λ is the wavelength of light, and n is the refractive index of the disk substrate.

Fig. 13 (c) shows an RF signal obtained by reproducing mark string 56 and pit string 53, corresponding to the case where the reflectance of the mark portion is smaller than the reflectance of the non-mark portion.

Fig. 13 (d) represents a tangential push-pull signal (TPP signal) obtained by reproducing mark string 56 and pit string 53. Since mark 55 in groove 54 as well as pit 52 are formed with the same constant depth, the TPP signal has the same polarity in all the marks and pits.

In the third conventional example, the relationship between pit 52 and the beam spot is similar to that of the first conventional example shown in Fig. 8. Therefore, the

RF signal and TPP signal are obtained by the following equations using outputs of two division photoreceptor elements A and B of detector 6.

$$RF = A + B$$

$$TPP = A - B$$

Experiments similar to those of the first conventional example were carried out in the third conventional example. From the results of experiments on a disk having a transparent substrate of 0.6 mm thickness and approximately 1.5 in refractive index using light of 650 nm in wavelength and an optical system having the NA of 0.65, a relationship similar to the relationship of the amplitude of the RF signal and TPP signal and the pit length shown in Fig. 9 was obtained.

Specifically, the RF signal takes the maximum value when the pit depth is $\lambda/4n$ (108 nm), and the amplitude of the TPP signal takes the maximum value when the pit depth is $\lambda/8n$ (54 nm) and $3\lambda/8n$ (162 nm). The TPP signal has its polarity inverted at the boundary of pit depth $\lambda/4n$. The TPP takes a negative value in the region of $\lambda/4n <$ pit depth $< \lambda/2n$ (216 nm), as shown in Fig. 4.

An RF signal as shown in Fig. 13 (c) is obtained since the quantity of reflected light of the light beam is small at the pit portion and large at the non-pit portion, whereas the reflectance is small at the mark portion and large at the non-mark portion.

Referring to 13 (d), the TPP signal has the same polarity for all the pits since pit 52 is formed with a constant depth. The TPP signal at the mark portion has the same polarity as the pit.

[Problems to be Solved by the Invention]

In ROM disks, a greater capacity (larger region) is required for the lead-in region as the amount of information written in the lead-in increases. Therefore, the region that can be used by the user will be reduced. In recordable disks, a greater capacity (larger region) is required for the lead-in region as the amount of information written in the lead-in increases. There was a problem that the region where the user can write data is reduced.

From the standpoint of copyright protection, it is not desirable for the information in a ROM disk recorded with copyrighted contents to be easily copied to another recordable disk. However, since the conventional disk dedicated to reproduction has information recorded in the dimension of the plane direction of the substrate, it is theoretically possible to copy the information in the ROM disk to another recordable disk. The role of copyright protection is low. Similarly in a conventional recordable disk, information can be easily copied to another recordable disk in theory since the information is recorded in the dimension of the plane direction of the substrate using pits and marks. The role of copyright protection is low.

The present invention is directed to solving such problems, and provides an optical recording medium and a reproduction method and apparatus of optical recorded information that allows the capacity of lead-in to be increased without increasing the lead-in region even when the amount of information to be recorded in the lead-in region is increased, i.e., increasing the region that can be used by the user, as well as preventing copying (clone) of a ROM disk or recordable disk that is recorded with copyrighted contents.

Additionally, the present invention provides an identification method and identification apparatus that identifies identification information unique to an optical recording medium.

[Means for Solving the Problems]

In view of the foregoing problem, the first technical means of the present invention is an optical recording medium including, on a substrate, a region having information recorded in at least a depth direction of a plane direction and depth direction of the substrate, and a region having information recorded in the plane direction of said substrate.

The second technical means is an optical recording medium including, on a substrate, a region having information recorded by at least a depth of a pit of the presence/absence, length, width, position, and depth of a pit, and a region having

information recorded by at least one of the presence/absence, length, width, and position of a pit.

The third technical means is characterized in that the optical recording medium of the second technical means includes a region having information recorded in a depth direction of pits having at least two different depths on said substrate.

The fourth technical means is characterized in that the polarity of a tangential push-pull signal obtained from pits having at least two different depths differs in the region having information recorded in the depth direction by pits having at least two different depths in the optical recording medium of the third technical means.

The fifth technical means is characterized in that said pits having two different depths (D1, D2) satisfies

$$\lambda/8n < D1 < \lambda/4n \text{ and } \lambda/4n < D2 < 3\lambda/8n$$

where λ is the wavelength of light employed in reproduction and n is the refractive index of the substrate in the region having information recorded in the depth direction by said pits having at least two different depths in the optical recording medium of the third or fourth technical means.

The sixth technical means is characterized in that additional information is recorded in at least the depth direction in the region having information recorded in at least the depth direction of the plane direction and the depth direction of said substrate in the optical recording medium of the first to fifth technical means.

The seventh technical means is characterized in that main information is recorded in the region having information recorded in the plane direction of said substrate in the optical recording medium of the sixth technical means.

The eighth technical means is characterized in that said additional information is information inhibited of being copied to another recording medium in the optical recording medium of the sixth or seventh technical means.

The ninth technical means is characterized in that said additional information includes information required for reproduction of said main information such as a cancel

key of scrambling or encryption of said main information in the optical recording medium of the sixth or seventh technical means.

The tenth technical means is characterized in that said additional information includes information unique to said optical recording medium such as identification (ID) information of said optical recording medium in the optical recording medium of the sixth or seventh technical means.

The eleventh technical means is characterized in that the presence of pits of different depths itself is the information to identify said optical recording medium in the region having information recorded in at least the depth direction of the plane direction and depth direction of said substrate in the optical recording medium of the first to fifth technical means.

The twelfth technical means is characterized in a reproduction method of optical recorded information reproducing recorded data based on the polarity of a tangential push-pull signal obtained from said pit in the region having information recorded by pits having at least two different depths on an optical recording medium.

The thirteenth technical means is characterized in a reproduction method of optical recorded information reproducing recorded information based on a combination of a signal according to a quantity of reflected light obtained from said pit and the polarity of the tangential push-pull signal obtained from said pit in the region having information recorded by pits having at least two different depths on an optical recording medium.

The fourteenth technical means is characterized in that recorded data is reproduced from the signal according to the quantity of reflected light at the region having information recorded by at least one of the absence/presence, length, width, and position of a pit on said optical recording medium in the reproduction method of optical recorded information of the twelfth or thirteenth technical means.

The fifteenth technical means is characterized in a reproduction apparatus of optical recorded information reproducing recorded data based on a polarity of a

tangential push-pull signal obtained from said pit in the region having information recorded by pits having at least two different depths on an optical recording medium.

The sixteenth technical means is characterized in a reproduction apparatus of optical recorded information reproducing recorded data based on a combination of a signal according to the quantity of reflected light obtained from said pit and the polarity of the tangential push-pull signal obtained from said pit in the region having information recorded by pits having at least two different depths on an optical recording medium.

The seventeenth technical means is characterized in a reproduction apparatus of an optical recording medium reproducing recorded data from the signal according to the quantity of reflected light at the region having information recorded by at least one of the absence/presence, length, width, and position of a pit on said optical recording medium in the reproduction apparatus of optical recorded information of the fifteenth or sixteenth technical means.

The eighteenth technical means is characterized in an identification apparatus of an optical recording medium identifying said optical recording medium based on the polarity of a tangential push-pull signal obtained from said pit in the optical recording medium wherein the presence of pits of different depths itself is unique identification information in the region having information recorded by pits of different depths in at least the depth direction of the plane direction and depth direction of a substrate.

The nineteenth technical means is characterized in an identification apparatus of an optical recording medium identifying said unique identification information based on the polarity of the tangential push-pull signal obtained from said pit wherein the presence of pits of different depths itself is the unique identification information in the identification method of optical recorded information including a region having information recorded in the depth direction by pits of different depths on the substrate.

The twentieth technical means is characterized in a recordable optical recording medium including a region having information recorded in at least the depth direction of a plane direction and depth direction of the substrate, and a recordable region of

information in the plane direction of said substrate.

The twenty-first technical means is characterized in a recordable optical recording medium including, on a substrate, a region having information recorded by at least a depth of a pit of the absence/presence, length, width, position and depth of a pit, and a recordable region of information by at least one of the absence/presence, length width, and position of a mark.

The twenty-second technical means is characterized in including a region having information recorded in the depth direction by pits having at least two different depths on said substrate in the recordable optical recording medium of the twenty-first technical means.

The twenty-third technical means is characterized in that the polarity of a tangential push-pull signal obtained from said pits having at least two different depths differs in the region having information recorded in the depth direction by pits having at least two different depths in the recordable optical recording medium of the twenty-second technical means.

The twenty-fourth technical means is characterized in that pits having at least two different depths (D2, D2) are set to satisfy

$\lambda/8n < D1 < \lambda/4n$ and $\lambda/4n < D2 < 3\lambda/8n$

where λ is a wavelength of light used in reproduction, and n is a refractive index of the substrate in the region having information recorded in the depth direction by pits having at least two different depths in the recordable optical recording medium of the twenty-second or twenty-third technical means.

The twenty-fifth technical means is characterized in that additional information is recorded in at least the depth direction in the region having information recorded in at least the depth direction of the plane direction and depth direction of said substrate in the recordable optical recording medium of the twentieth to twenty-fourth technical means.

The twenty-sixth technical means is characterized in that main information is

recorded in the region having information recorded in the plane direction of said substrate in the recordable optical recording medium of the twenty-fifth technical means.

The twenty-seventh technical means is characterized in that additional information includes information inhibited of being copied into another recording medium in the recordable optical recording medium of the twenty-fifth or twenty-sixth technical means.

The twenty-eighth technical means is characterized in that said additional information includes information required for reproduction of said main information such as a cancel key of scrambling or encryption of said main information in the recordable optical recording medium of the twenty-fifth or twenty-sixth technical means.

The twenty-ninth technical means is characterized in that said additional information includes information unique to said optical recording medium such as identification (ID) information of said optical recording medium in the recordable optical recording medium of the twenty-fifth or twenty-sixth technical means.

The thirtieth technical means is characterized in a reproduction method of recordable optical recorded information, wherein recorded information is reproduced based on a polarity of at least a tangential push-pull signal obtained from pits having at least two different depths in a region having information recorded by said pits having at least two different depths on an optical recording medium, and recorded information is reproduced from a signal based on at least a quantity of reflected light at a region having information recorded by a mark.

The thirty-first technical means is characterized in a reproduction apparatus of recordable optical recorded information, wherein recorded information is reproduced based on a polarity of at least a tangential push-pull signal obtained from pits having at least two different depths in a region having information recorded by said pits having at least two different depths on an optical recording medium, and recorded information is reproduced from a signal based on at least a quantity of reflected light at a region having information recorded by a mark.

[Embodiments of the Invention]

First to third embodiments of the present invention will be described hereinafter with reference to Figs. 1-5.

(First Embodiment)

A first embodiment of the present invention will be described based on Figs. 1-3.

Fig. 1 includes a schematic diagram of a structure of a pit string on a ROM disk of the first embodiment, and waveforms of signals obtained in reproducing recorded information from the ROM disk.

Fig. 1 (a) shows the arrangement of pits 2 in 1 row from the inner circumference to the outer circumference of substrate 1.

Fig. 1 (b) schematically shows a cross section of a disk, wherein the lead-in region is formed of a shallow pit 2a (depth D1) and a deep pit 2b (depth D2), and the user region is formed of a pit 2a of a constant depth (depth D1).

Fig. 1 (c) represents an RF signal employed in reproducing pit string 3, reflecting the reduction of the quantity of reflected light at the pit portion.

Fig. 1 (d) represents a tangential push-pull signal (TPP signal) employed in reproducing pit string 3, wherein the polarity of the TPP signal differs in deep pit 2b from that of shallow pit 2a in accordance with the lead-in being formed of pits 2a and 2b of two different depths. By employing pits 2a and 2b of two different depths, information can be recorded in the depth direction taking advantage of the positive and negative values that are easily determined as to the polarity of the TPP signal.

These two pit depths (D1, D2) are to be set so that the RF signal of the same amplitude and TPP signal of different polarity are obtained from pits 2a and 2b.

Therefore, similarly to the description provided in association with the first conventional example, it will be understood from Fig. 9 that selection is to be made so as to satisfy

$\lambda/8n < D1 < \lambda/4n$ and $\lambda/4n < D2 < 3\lambda/8n$

where λ is the wavelength of light employed in reproduction, and n is the refractive

index of the substrate.

The reproduction method and reproduction apparatus with respect to the lead-in and user region formed of two pits 2a and 2b of two different depths will be described here with reference to Figs. 2 and 3.

Fig. 2 is a block diagram showing the structure of the main elements of a reproduction apparatus, and Fig. 3 includes waveforms and timing charts representing the method and operation of reproduction of the reproduction apparatus.

Consider the case where pits 2a and 2b arranged as shown in Fig. 3 (a) are to be reproduced. It is assumed that the depth of the pits in Fig. 3 are D1, D2 and D1 from left to right.

The outputs of a detector 6 based on reflected light 5 of the beam spot directed to photoreceptor elements A and B have the difference therebetween obtained by a differential amplifier 7 to be provided as a TPP signal (Fig. 3 (c)), and the total sum are obtained by an addition amplifier 8 to be provided as an RF signal (Fig. 3 (b)).

A correction process of frequency characteristics is carried out by an equalization circuit 12 on an RF signal reproduced from a pit of a particularly short length. Then, binarization is conducted by a binarization circuit 13 (Fig. 3 (d)) for transmission to a demodulation circuit not shown.

The TPP signal is compared with the positive reference value by a comparator 9. When the value is greater than the reference value (i.e., the sign is positive and absolute value thereof is great), a pulse (+1) is output to an adder-subtracter circuit 11 (Fig. 3 (e)). Similarly, a comparator 10 compares the TPP signal with a negative reference value. When it is smaller than the negative reference value (the sign is negative, and absolute value is large), a pulse (−1) is output to adder-subtracter circuit 11 (Fig. 3 (f)). Adder-subtracter circuit 11 adds the pulses from comparators 9 and 10 to provide the three statuses of −1, 0, +1 as an output signal of 2 bits (Fig. 3 (g)).

In other words, adder-subtracter circuit 11 operates on two sets of pulse signals (in the present example, adding including the polarity thereof) binarized through

comparators 9 and 10 based on a TPP signal (tangential push-signal). Based on the operation result, the two statutes of −1 or +1 can be restored/reproduced according to the depth of the pit in the pit portion (i.e., the output sequence of positive and negative pulses on the TPP signal) and the status of 0 can be restored at the non-pit portion where a pit is not formed. Reproduction of recorded information of the total of 3 values by the absence/presence and depth of a pit is allowed. Therefore, the recording density of information on an optical recording medium can be improved significantly, as compared to the conventional so-called binary recording.

In order to reproduce recorded information similar to the conventional binary recording reproduction, all the pits should have the same depth. Referring to Fig. 3, in the pit of depth D1, for example, a positive tangential push-pull signal (TPP signal) and then a negative TPP signal are generated when the beam spot is located at the leading edge and trailing edge, respectively (Fig. 3 (c)). By adding the pulses of Fig. 3 (e)), the status of +1 and the status of 0 are obtained at the pit portion and the non-pit portion, respectively.

In other words, in the reproduction method or apparatus of recorded information, the region having main information recorded according to pits of the same depth can have binarization information stored and reproduced. The lead-in region having different depths can have three-valued information restored and reproduced. The same reproduction method can be applied to either region.

As to the region having the main information recorded according to pits of the same depth, the binarization information may be reproduced based on only a produced RF signal, as in the conventional case. In this case, a conventional device can be used for the reproduction circuit of the main information. This contributes to reducing the cost of the reproduction apparatus.

In the lead-in of the optical disk of the present invention, information is recorded, not only in the plane direction of substrate 1, but also in the depth direction. Therefore, more information can be recorded in the lead-in as compared to a conventional ROM

disk having information recorded only in the plane direction. This means that the region that can be used by the user can be increased as compared to that of the conventional case, even if the amount of information written in the lead-in increases.

Furthermore, copyright protection can be effected by recording information in the depth direction in the lead-in region. This will be described hereinafter.

As described in relation to the third conventional example of Fig. 13, the polarity of the TPP signal is identical for all marks 55, as shown in Fig. 13 (d), since recording marks 55 have the same depth in the recordable disk. Therefore, the information recorded in the depth direction by pits of different depths of the information in the ROM disk produced as shown in Fig. 1 will by no means to be transferred to a recordable disk. In other words, the lead-in of an optical disk in accordance with the present invention can never be copied to another recordable disk.

By scrambling or encrypting the information in the user region and recording a cancel key thereof in the pit portion by the depth direction, the cancel key will by no means be copied even if the information in the user region is copied to a recordable disk. This means that the information in the ROM disk according to the present invention substantially cannot be copied.

Information unique to the disk such as identification (ID) information of the disk and the like other than the cancel key set forth above can be recorded similarly in the depth direction in the lead-in region. As such, undesirable copying into a recordable disk can be inhibited completely. In other words, illegal copy of a disk that includes copyrighted contents can be prevented.

Although the first embodiment corresponds to the case where information is recorded in at least the depth direction of the lead-in region, it is apparent that the region where recording is to be effected in the depth direction is not limited to a lead-in region, and can be effected on any region of the medium. More specifically, it is impossible to copy information from a region where the information is recorded in the depth direction to another recordable disk. Such a region can be identified as a unique

region in the optical disk.

The first embodiment is directed to a transparent substrate having a thickness of 0.6 mm and a refractive index of 1.5 using light of 650 nm in wavelength and an optical system of 0.6 in NA. However, it is apparent that the effect of the present invention is not limited by the optical system or the substrate. Furthermore, the values of the pit depths are not limited to those shown in the above embodiment. According to the principle of the present invention, it is clear that depth are to be selected so that the polarity of the tangential push-pull signal differs. Since a recordable disk does not have a recording dimension in the depth direction, copying information from a disk having a region recorded with information in the depth direction to a recordable disk can be inhibited. It is apparent that the specific method therefor is not limited to that described in the present embodiment.

(Second Embodiment)

A second embodiment of the present invention will be described based on Fig. 4.

Fig. 4 is a block diagram of an apparatus detecting presence of pits from which a tangential push-pull signal (TPP signal) of different polarity can be obtained. Based on the output signals of comparators 9 and 10 of a configuration similar to that of the reproduction apparatus of the first embodiment shown in Fig. 2 and the RF signal compared with a reference value by comparator 14, a marker detection circuit 15 detects the presence of a pit from which a TPP signal of different polarity can be obtained.

By using such an apparatus, a phenomenon specific to a disk having information in the depth direction can be detected. Therefore, the presence of pits of different depths itself can be used as the so-called identification marker (ID) to identify that medium.

(Third Embodiment)

Fig. 5 includes a schematic diagram of a mark string 26 and a pit string 23 in a recordable disk of the third embodiment, illustrated in a linear version from the inner

circumference to the outer circumference of the disk, and waveforms of signals obtained in reproducing recorded information from the disk.

Mark 25 is written in either or both of the groove and land. Fig. 5 corresponds to the case where mark 25 is written in groove 24.

Fig. 5 (a) represents mark string 26 constituted by marks 25 formed in groove 24 and a pit string 23 arranged between mark string 26, illustrated in a linear version from the inner circumference to the outer circumference of the disk.

Fig. 5 (b) schematically shows a cross section of a disk in which holes are formed in a concave manner at the pit portion, formed of a shallow pit 22a (depth D1) and a deep pit 22b (depth D2). More specifically, the third embodiment differs from the third conventional example shown in Fig. 13 in that pits forming pit string 23 include a shallow pit 22a (depth D1) and a deep pit 22b (depth D2).

Fig. 5 (c) represents an RF signal obtained by reproducing mark string 26 and pit string 23. The quantity of reflected light of the mark portion and the pit portion is smaller than the quantity of reflected light of the non-mark portion and the non-pit portion.

Fig. 5 (d) represents a tangential push-pull signal (TPP signal) obtained by reproducing mark string 26 and pit string 23. The TPP signals obtained from mark 25 and shallow pit 22a have the same polarity, whereas the TPP signal obtained from deep pit 22b have opposite polarity. By using pits 22a and 22b of two different depths, information can be recorded in the depth direction making advantage of the positive and negative values based on the polarity of the TPP signal that can easily be determined.

These two different depths D1 and D2 are to be set so that an RF signal of the same amplitude and TPP signal of different polarity are obtained. It is therefore understood that the depth should be selected so as to satisfy

$$\lambda/8n < D1 < \lambda/4n \text{ and } \lambda/4n < D2 < 3\lambda/8n$$

where λ is the wavelength of light employed in reproduction and n is the refractive index of the substrate in accordance with Fig. 9, likewise the first embodiment.

The reproduction method and reproduction apparatus from a region formed of pits 22a and 22b having two different depths and the region where mark 25 is written are similar to the reproduction method and reproduction apparatus of the first embodiment described with reference to Figs. 2 and 3.

Similarly in the reproduction apparatus of the third embodiment, an adder-subtracter circuit 6 applies an operation on two sets of pulse signals (adding including polarity) obtained by binarizing TPP signals through comparators 8 and 9. Based on the results of the operation, the two statutes of −1 and +1 can be restored and reproduced according to the pit depths of the pit portion (in other words, the generating order of positive and negative pulses on the TPP signal). In the non-pit portion where a pit is not formed, the status of 0 can be restored. Therefore, information of the total of 3 values can be reproduced depending upon the absence/presence and depth of the pit. Thus, the recording density of information on the optical recording medium can be improved significantly than by the conventional so-called binary recording.

According to the reproduction method and reproduction apparatus of the third embodiment, the method in which the RF signal and TPP signal are combined as set forth above can be used to reproduce the mark portion. More specifically, referring to Fig. 5 (d), a positive TPP signal and a negative TPP signal are output when the beam spot is located at the leading edge and trailing edge, respectively, on mark 25. Therefore, similar to the case of the first embodiment, by accumulating pulse signals of Fig. 3 (e) (f), the status of +1 and the status of 0 can be achieved at the mark portion and the non-mark portion, respectively.

In accordance with the reproduction method or apparatus of the recorded information, binarization information for the mark portion and ternary information for the pit portions of different depths can be respectively restored and reproduced. The same reproduction method can be applied for either region.

As shown in the third conventional example of Fig. 13, the binarization information reproduction method based on RF signals alone may be employed as in the

conventional case for a region where main information is recorded with pits of the same depths. In this case, the conventional circuit can be used for the reproduction circuit of the main information, contributing to reducing the cost of the reproduction apparatus.

Since the lead-in of the recordable optical disk of the present invention has information recorded in the depth information in addition to the plane information of the substrate, more information can be recorded in the lead-in as compared to the conventional recordable disk having information recorded in only the plane direction. This means that the region that can be used by the user can be increased as compared to the conventional one, even when the amount of information written in the lead-in is increased.

By recording information in the depth direction in the lead-in in the third embodiment shown in Fig. 5, copyright protection can be effected. This will be described hereinafter.

Since the depth of the recording mark in the recordable region of the recordable disk is constant, the polarity of the TPP signal is identical for all the marks, as shown in Fig. 5 (d). Therefore, the region recorded in the depth direction by pits of the information of the recordable disk of Fig. 5 will by no means be transferred to a recordable disk. In other words, information at the pit portion in the lead-in of the optical disk of the present invention cannot be copied to a recordable disk.

By scrambling or encrypting the information in the user region and write a cancel key thereof in the pit portion based on the depth direction, the cancel key recorded at the lead-in region will never be copied even if the information in the user region is copied into another recordable disk. Therefore, copying information in the recordable disk by the third embodiment is substatially inhibited. It is to be noted that information unique to the disk such as disk identification (ID) information other than the cancel key may be similarly recorded based on the depth direction in the pit portion. By such recording, undesirable copying of these information to another recordable disk can be inhibited completely. In other words, illegal copying of a disk that includes

copyrighted contents can be prevented.

In the third embodiment, a transparent substrate having the thickness of 0.6 mm and the refractive index of 1.5 is employed based on light of 650 nm in wavelength and an optical system of 0.6 in NA. It is apparent that the effect of the present invention is not limited to the optical system and substrate. Furthermore, the values of the pit depths are not limited to those shown in the above embodiment. According to the principle of the present invention, it is clear that depths are to be selected so that the polarity of the tangential push-pull signal differs. Furthermore, since a recordable region of a recordable disk is absent of a recording dimension in the depth direction, copying information from a disk having a region recorded with information in the depth direction to another recordable disk can be inhibited. It is apparent that the specific method therefor is not limited to that described in the present embodiment.

[Effects of the Invention]

The optical recording medium of claims 1 and 2 includes, on a substrate, a region having information recorded in at least a depth direction of a plane direction and depth direction of the substrate, and a region having information recorded in the plane direction of said substrate. Therefore, the recording density can be increased in the region having information recorded in the depth direction, as compared to a conventional optical recording medium, allowing the recording of more information.

The optical recording medium of claim 3 includes a region having information recorded in the depth direction by pits having at least two different depths in the optical recording medium of claim 2. Therefore, recording of information in the depth direction can be conducted reliably to improve the reliability of information.

The optical recording medium of claim 4 has different polarities of the TPP signal obtained from the pit of respective depths in the optical recording medium of claim 3. Therefore, reproduction of information recorded in the depth direction can be conducted reliably to improve the reliability of information reproduction.

The optical recording medium of claim 5 has the depths D1 and D2 of the pit set

so as to satisfy $\lambda/8n < D1 < \lambda/4n$ and $\lambda/4n < D2 < 3\lambda/8n$ in the optical recording medium of claim 3. Therefore, signals of a large amplitude can be achieved for both the RF signal and TPP signal with favorable balance to improve the signal quality during reproduction and reduce reproduction error.

The optical recording medium of claims 6 and 7 has additional information recorded in at least the depth direction in the regions having information recorded in at least the depth direction, and main information recorded in the region having information recorded in the plane direction in the optical recording medium of claims 1-5. Therefore, a large region for main information can be achieved. Also, copying of additional information to another recordable disk can be prevented.

In the optical recording medium of claim 8, additional information includes information inhibited of being copied to another recording medium in the optical recording medium of claims 6 and 7. Therefore, copying of additional information inhibited of copying to a recordable disk can be prevented.

In the optical recording medium of claim 9, additional information includes information required for reproduction of said main information such as a cancel key of the scrambling or encryption of main information in the optical recording medium of claims 6 and 7. Therefore, copying of information required for reproduction of main information such as a cancel key of the scrambling or encryption of main information into a recordable disk can be prevented.

In the optical recording medium of claim 10, the additional information includes identification (ID) information of the medium, or information specific to the medium, in the optical recording medium of claims 6 and 7. Therefore, copying of identification (ID) information of the medium or information specific to the medium or information specific to the medium to a recordable disk can be prevented.

The optical recording medium of claim 11 includes a region having information recorded in at least the depth direction, and the presence of pits of different depths itself is the identification information of the medium, in the optical recording medium of

claims 1-5. Therefore, copying of identification (ID) information of an optical recording medium, or information specific to the optical recording medium into a recordable disk can be prevented.

The reproduction method and reproduction apparatus of optical recorded information of claims 12, 13, 15 and 16 have recorded information reproduced based on the TPP signal, or a combination of the RF signal and TPP signal according to the quantity of reflected light in an optical recording medium. Therefore, recorded data of multi-bits can be reproduced than by the reproduction of binary recorded data based on just the RF signal according to the quantity of reflected light as in the conventional case.

The reproduction method and reproduction apparatus of an optical recording medium of claims 14 and 17 have recorded data reproduced from a signal according to the quantity of reflected light at the region having information recorded by at least one of the presence/absence, length, width and position of a pit in the reproduction method and reproduction apparatus of claims 12, 13, 15 and 16. Therefore, the conventional reproduction circuit can be used for the reproduction circuit of this region, allowing reduction in the cost of the reproduction apparatus.

In the identification method and identification apparatus of an optical recording medium of claims 18 and 19, said optical recording medium can be identified based on the polarity of a TPP signal obtained from the pits of the optical recording medium in which the presence of pits of different depths itself is the identification information unique to that optical recording medium. Therefore, identification of an optical recording medium can be conducted reliably.

The optical recording medium of claims 20 and 21 includes, on a substrate, a region having information recorded in at least a depth direction of a plane direction and depth direction of the substrate, and a region that can have information recorded in the plane direction of said substrate. Therefore, the recording density can be increased in the region having information recorded in the depth direction, as compared to a conventional optical recording medium to allow recording of more information.

The optical recording medium of claim 22 includes a region having information recorded in a depth direction by pits having at least two different depths in the optical recording medium of claim 21. Therefore, recording of information in the depth direction can be conducted reliably to improve reliability of information.

In the optical recording medium of claim 23, the polarity of the TPP signal obtained from pits of respective depths differs in the optical recording medium of claim 22. Therefore, reproduction of recorded information in the depth direction can be conducted reliably to improve reliability of information reproduction.

In the optical recording medium of claim 24, the depths D1 and D2 of the pits are set so as to satisfy $\lambda/8n < D1 < \lambda/4n$ and $\lambda/4n < D2 < 3\lambda/8n$ in the optical recording medium of claim 22 or 23. Therefore, signals of large amplitude can be achieved in both the RF signal and TPP signal with favorable balance. The signal quality can be improved and reproduction error reduced in reproduction.

The optical recording medium of claims 25 and 26 has additional information recorded in at least the depth direction in the region having information recorded in at least the depth direction, and main information recorded in the region having information recorded in the plane direction in the optical recording medium of claims 20-24. Therefore, a large region for main information can be provided. Also, copying of additional information to another recordable disk can be prevented.

In the optical recording medium of claim 27, additional information includes information inhibited of being copied to another recording medium in the optical recording medium of claim 25 or 26. Therefore, copying of additional information inhibited of being copied into another recordable disk can be prevented.

In the optical recording medium of claim 28, the additional information includes information required for reproduction of said main information such as a cancel key of the scrambling and encryption of main information in the optical recording medium of claims 25 and 26. Therefore, copying of information required for reproduction of said main information such as a cancel key of scrambling and encryption of main information

into another recordable disk can be prevented.

In the optical recording medium of claim 29, additional information includes identification (ID) information of that optical recording medium, or information unique to the optical recording medium in the optical recording medium of claims 25 and 26. Therefore, copying of identification (ID) information of a medium or information unique to the optical recording medium into another recordable disk can be prevented.

The reproduction method and reproduction apparatus of the optical recording information of claims 30 and 31 have recorded information reproduced based on the polarity of at least the TPP signal in the region having information recorded with pits of at least two different depths, and recorded information reproduced from a signal according to the quantity of reflected light in the region where recording was conducted based on a mark. Therefore, multibit recorded data can be reproduced in the pit region, and binary recorded data can be reproduced in the mark region.

[Brief Description of the Drawings]

Fig. 1 includes a schematic diagram of a configuration of an ROM disk of the first embodiment, and waveforms of signals obtained in reproducing recorded information from the ROM disk.

Fig. 2 is a block diagram of the configuration of main elements of the reproduction apparatus of the first embodiment of the present invention.

Fig. 3 shows the reproduction method of the reproduction apparatus of Fig. 2, the operation, and waveforms and timing in operation.

Fig. 4 is a block diagram showing a configuration of the main elements of the identification apparatus of the second embodiment of the present invention.

Fig. 5 includes schematic diagrams of the configuration of mark strings and pit strings in the recordable disk of the third embodiment according to the present invention, and waveforms of signals obtained in reproducing recorded information from the recordable disk.

Fig. 6 is a schematic diagram of the arrangement of pits recorded on a ROM disk

of the first conventional example.

Fig. 7 includes schematic diagrams of a configuration of pit string of the ROM disk of the first conventional example, and waveforms of signals obtained when reproducing recorded information from the ROM disk.

Fig. 8 shows the manner of scanning the pit string with a beam spot, and receiving the reflected light of the beam spot at a detector.

Fig. 9 represents the relationship between the pit depth and the amplitudes of an RF signal and tangential push-pull signal (TPP signal).

Fig. 10 shows an RF signal and TPP signal when reproducing from pits of different depths.

Fig. 11 includes schematic diagrams of a configuration of a mark string of a recordable disk of the second conventional example, and waveforms of signal obtained in reproducing recorded information from a recordable disk.

Fig. 12 is a schematic diagram of a configuration of non-recording in a recordable disk using the phase change recording layer of the third conventional example.

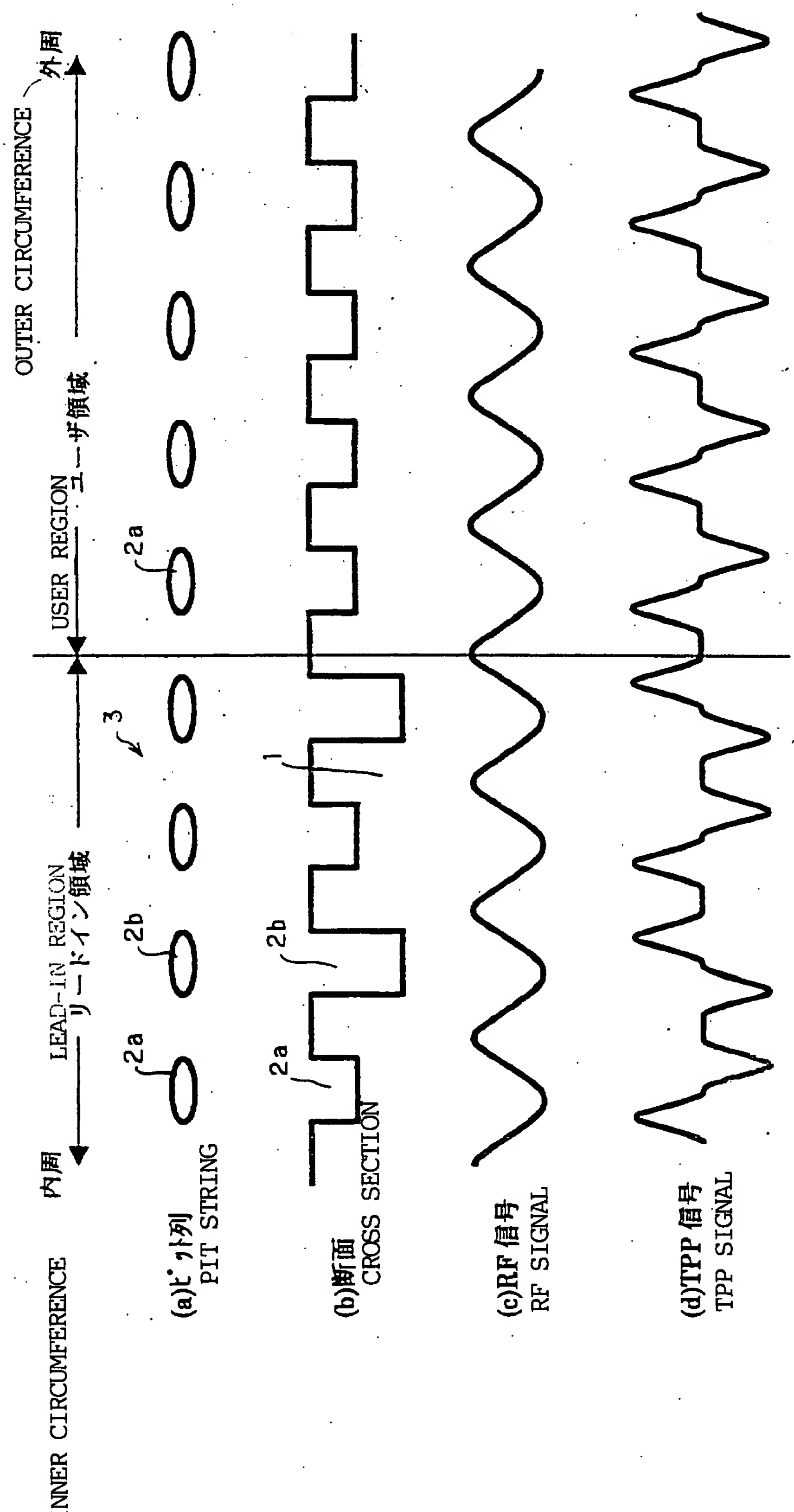
Fig. 13 includes a schematic diagram of a configuration of a pit string and pit string of the recordable disk of the third conventional example, and waveforms of signals obtained in reproducing recorded information from the recordable disk.

[Description of the Character Numbers]

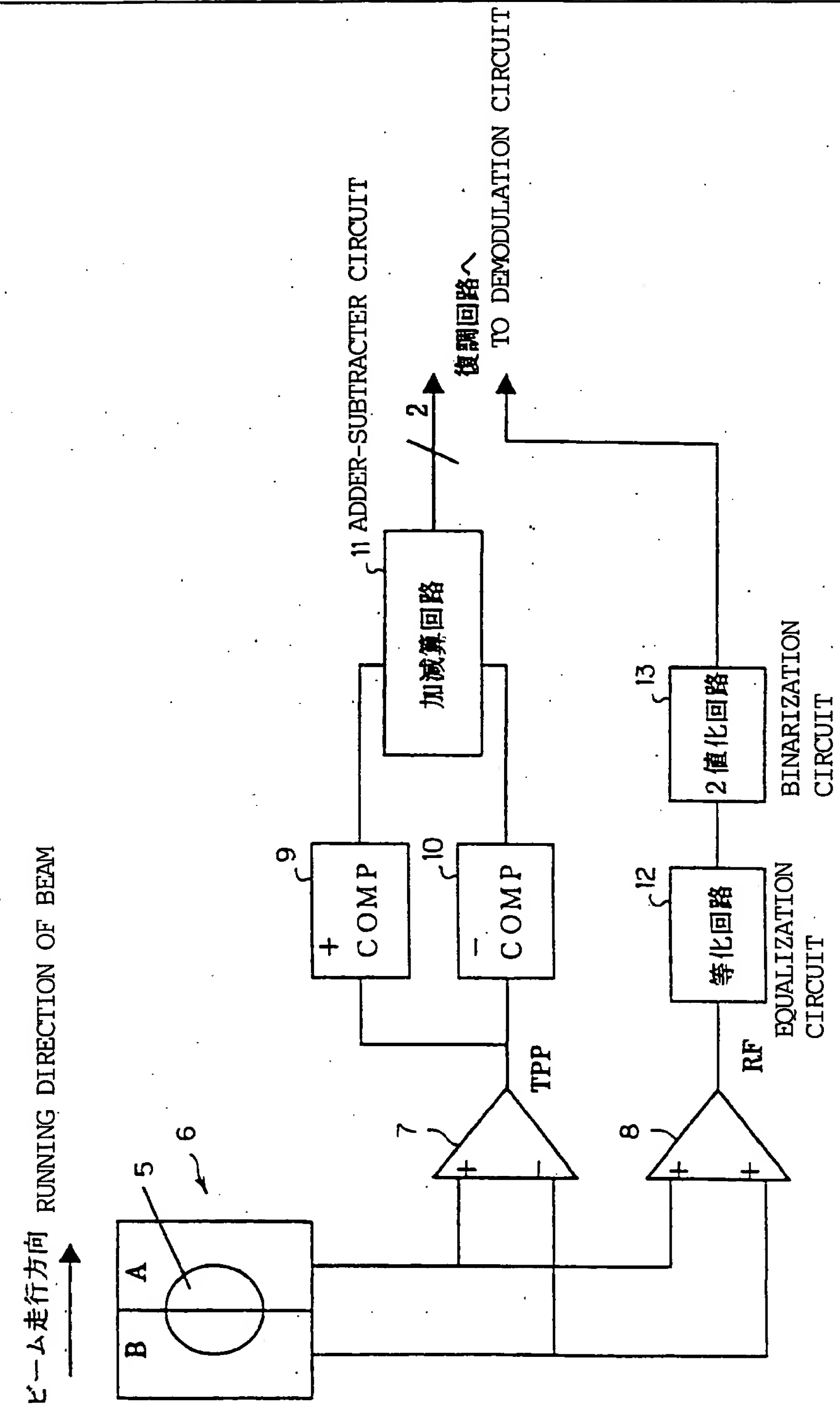
1, 21, 31, 41, 51 ... substrate; 2, 22, 32, 52 ... pit; 3, 23, 33, 53 ... pit string; 5 ... reflected light; 6 ... detector; 7 ... differential amplifier; 8 ... addition amplifier; 9, 10, 14 ... comparator; 11 ... adder-subtracter circuit; 12 ... equivalent circuit; 13 ... binarization circuit; 15 ... marker detection circuit; 24, 44, 54 ... groove; 25, 45, 55 ... mark; 26, 46, 56 ... mark string; 34 ... beam spot; 35 ... reflected light; 36 ... two division photoreceptor element; 37 ... detector.

【書類名】　図面
Document Name　Drawings

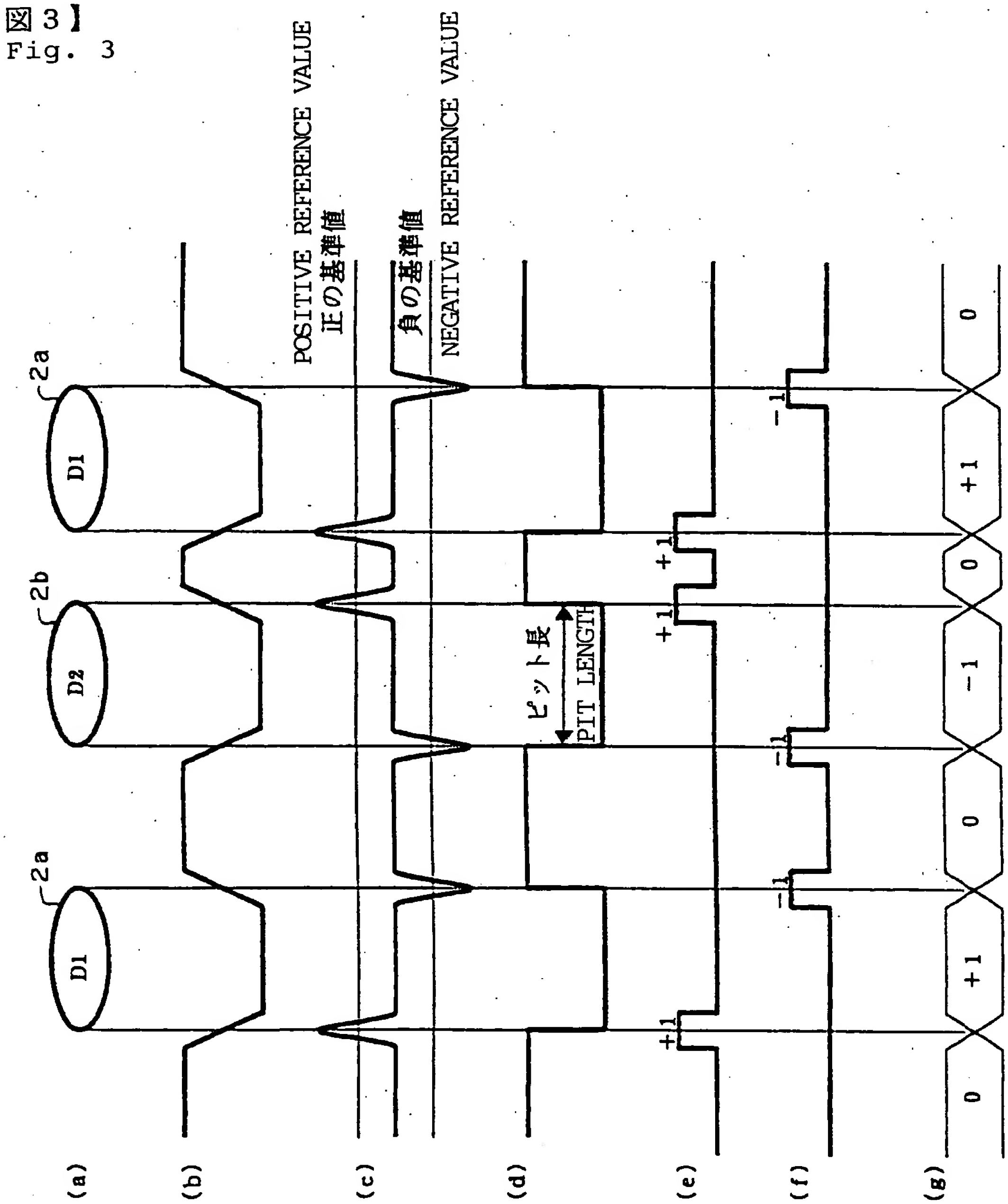
【図１】
Fig. 1



【図２】
Fig. 2


ビーム走行方向
RUNNING DIRECTION OF BEAM
A
B
5
6
7
8
TPP
RF
9
+
COMP
10
-
COMP
12
等化回路
EQUALIZATION CIRCUIT
13
2値化回路
BINARIZATION CIRCUIT
加減算回路
11 ADDER-SUBTRACTER CIRCUIT
2
復調回路へ
TO DEMODULATION CIRCUIT

【図３】
Fig. 3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正の基準値
負の基準値
NEGATIVE REFERENCE VALUE
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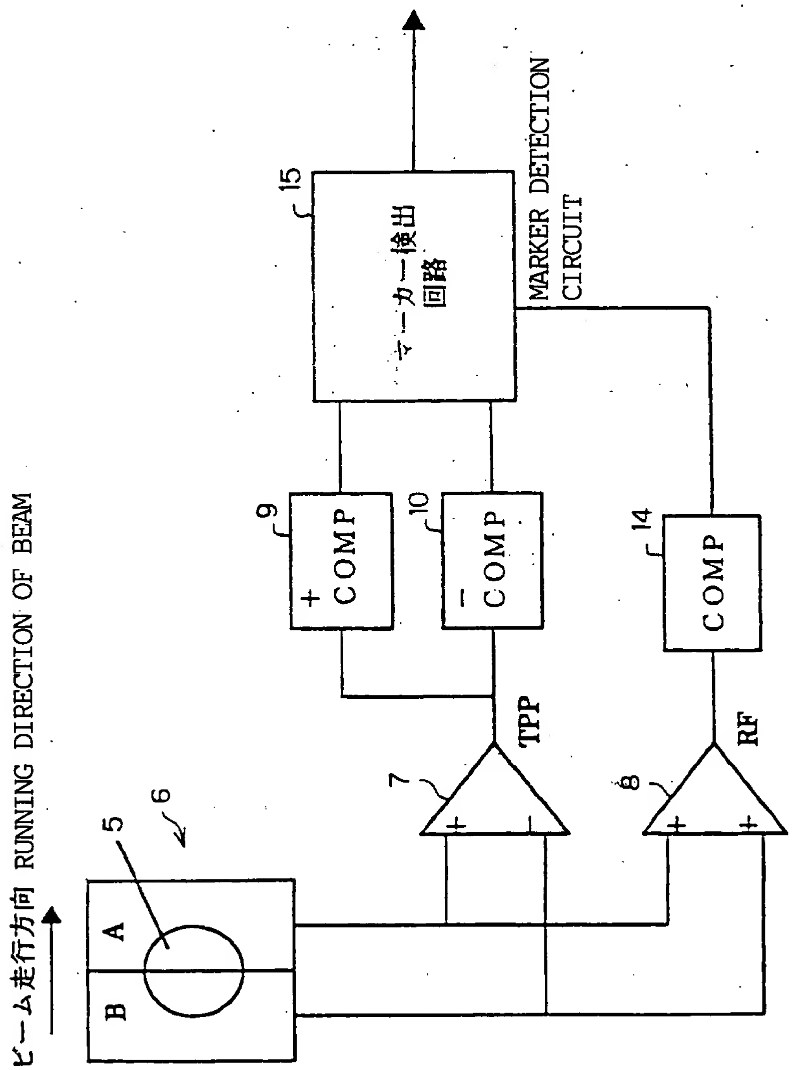
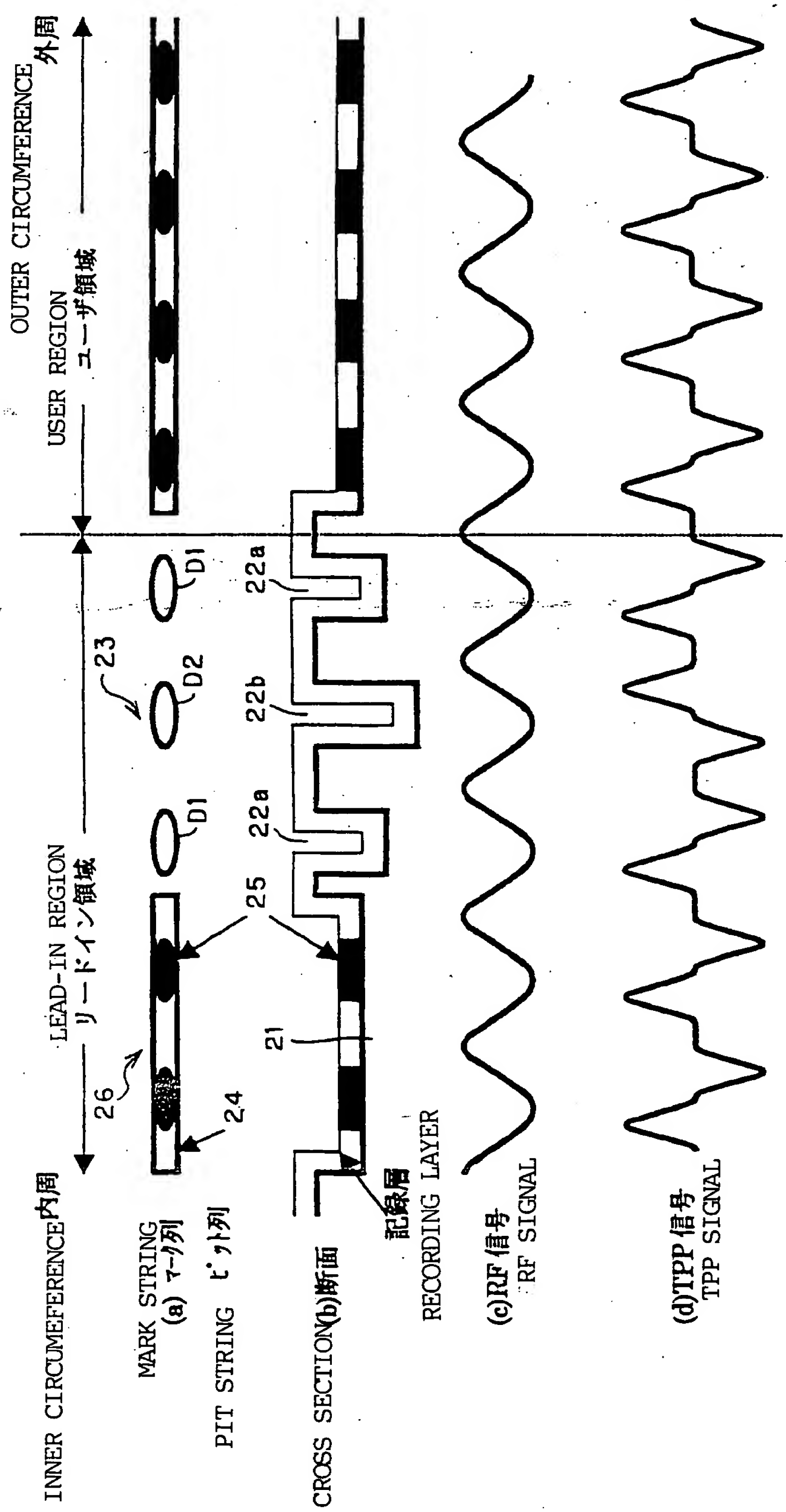
D1
2b
D2
ピット長
PIT LENGTH
+1
-1
0
(a)
(b)
(c)
(d)
(e)
(f)
(g)

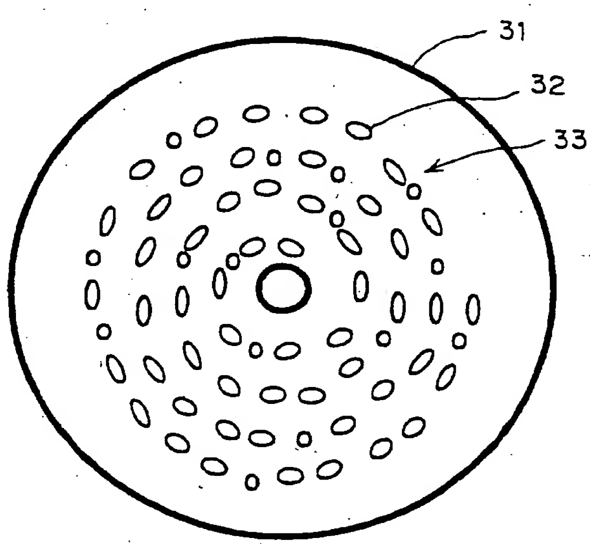
【図４】
Fig. 4


ビーム走行方向 RUNNING DIRECTION OF BEAM
A
B
5
6
7
8
TPP
RF
+
−
COMP
9
10
14
15
マーカー検出
回路
MARKER DETECTION
CIRCUIT

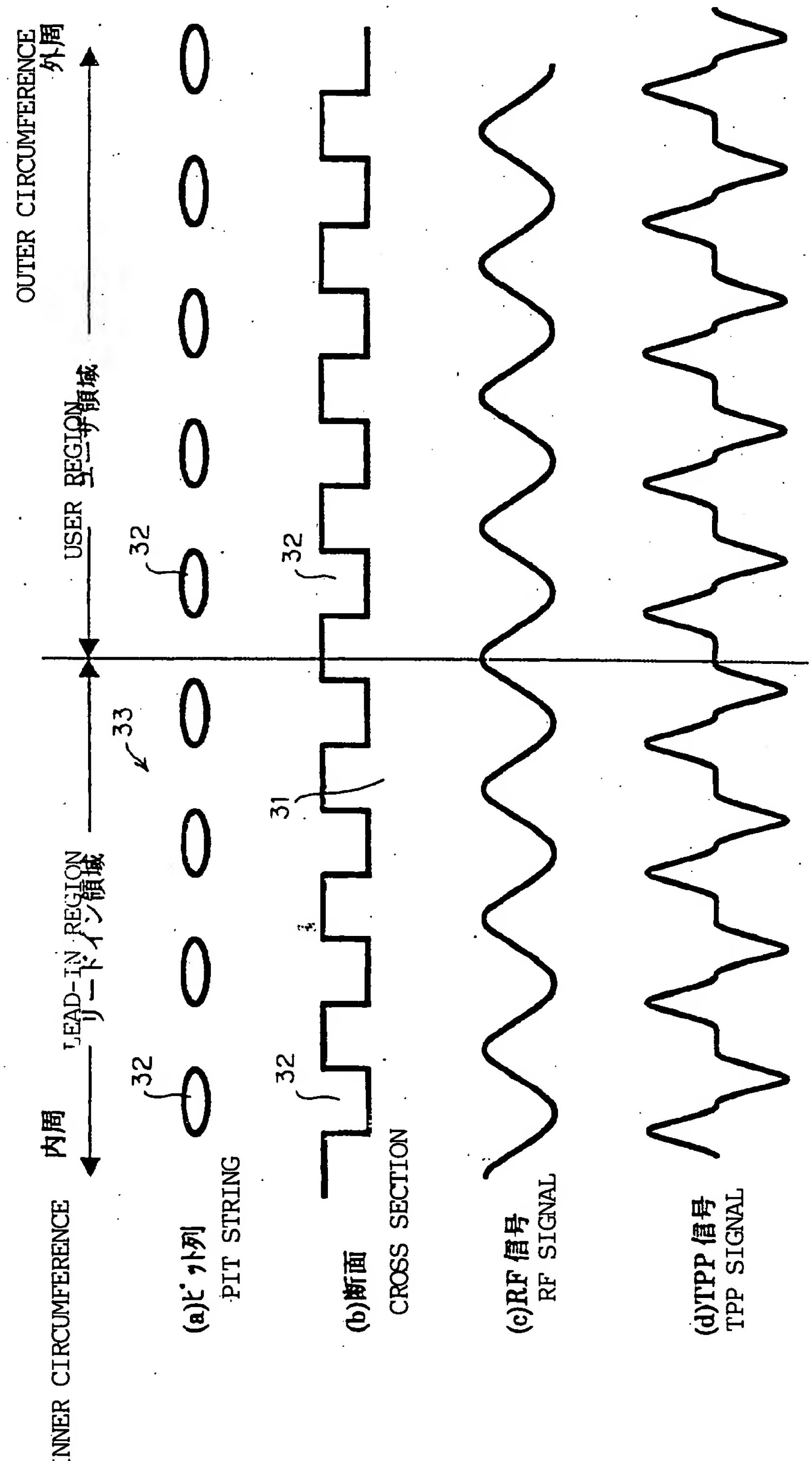
【図５】
Fig. 5


OUTER CIRCUMFERENCE外周
USER REGION　ユーザ領域
LEAD-IN REGION　リードイン領域
INNER CIRCUMEFERENCE内周
MARK STRING (a) マーク列
PIT STRING ピット列
CROSS SECTION (b)断面
記録層
RECORDING LAYER
(c)RF信号
RF SIGNAL
(d)TPP信号
TPP SIGNAL
D1
D2
D1
22a
22b
22a
23
25
26
24
21

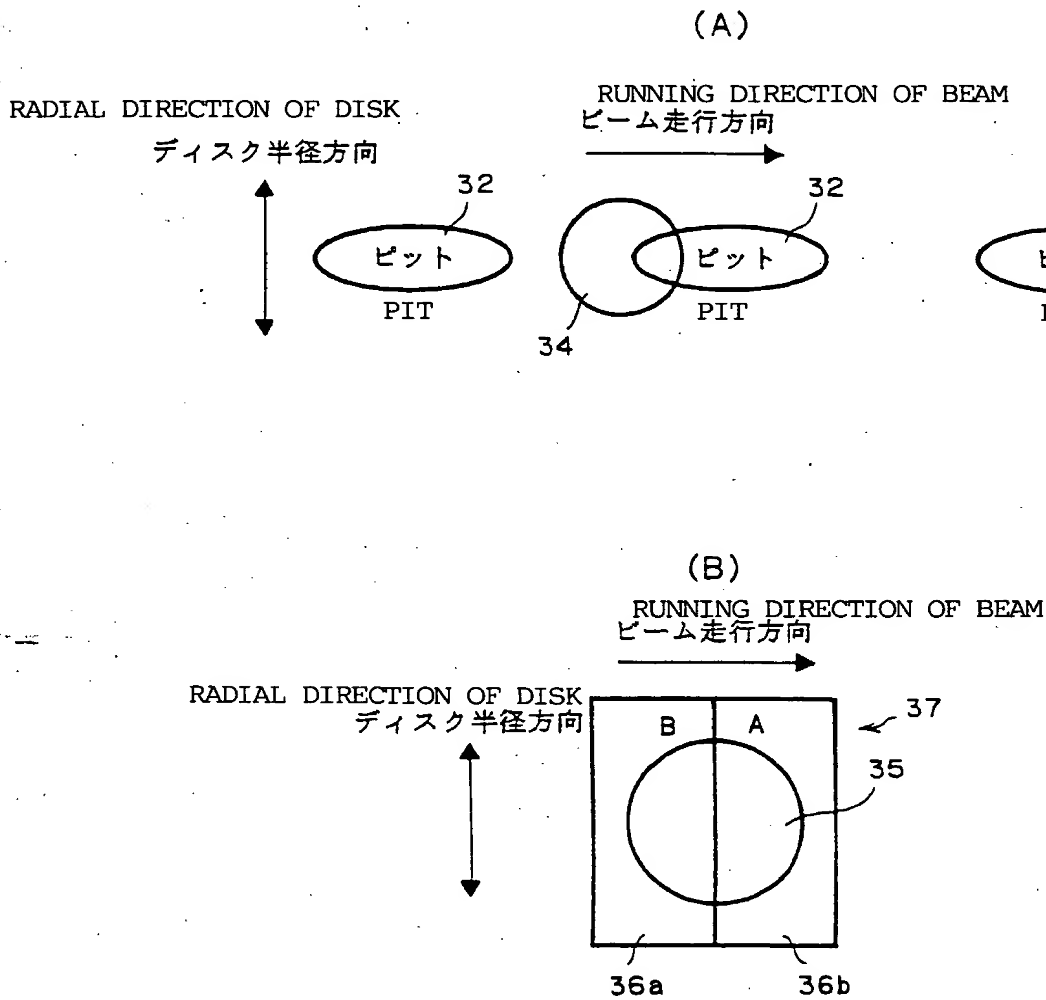
【図６】
Fig. 6



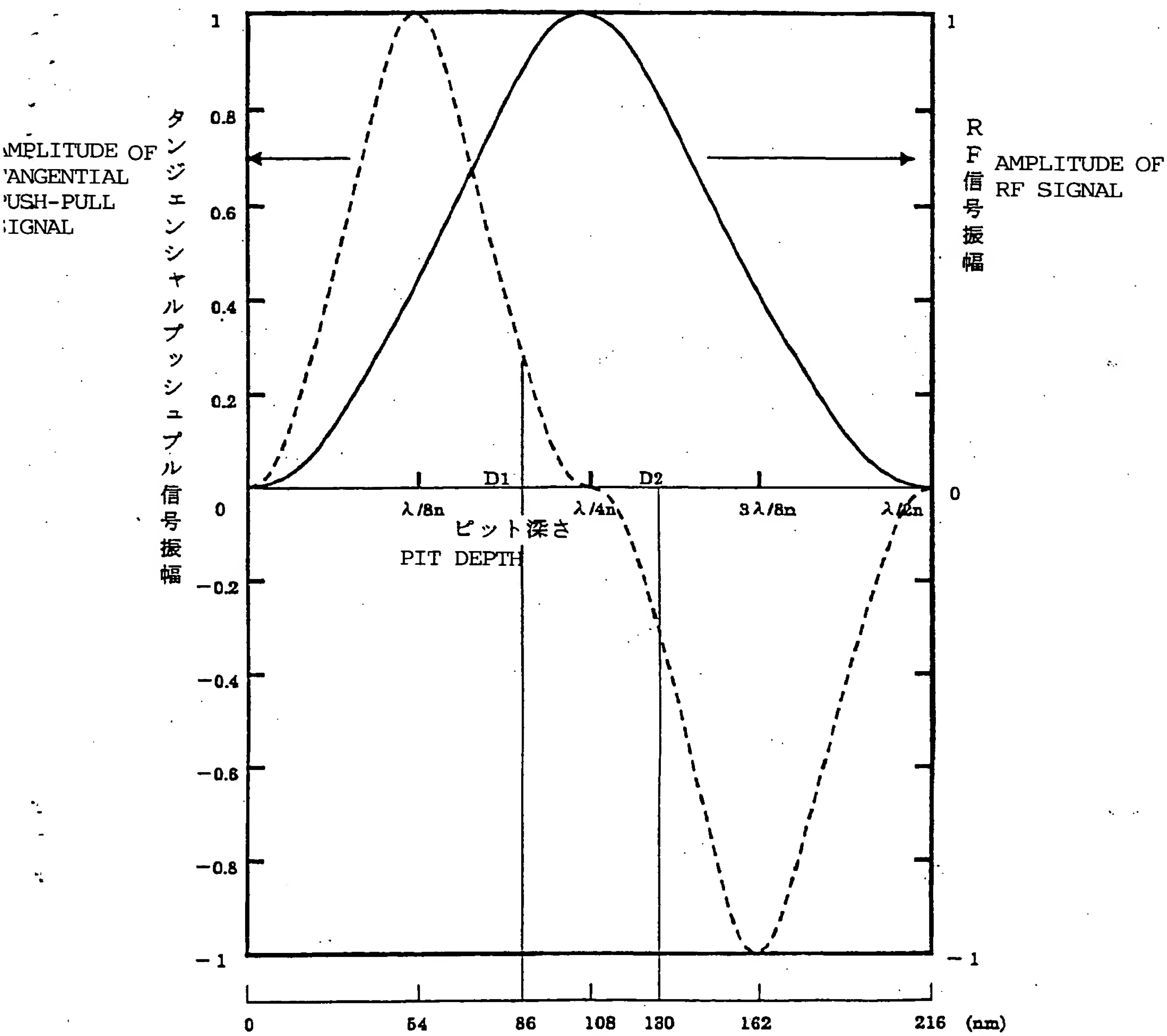
【図７】
Fig. 7


OUTER CIRCUMFERENCE
外周
USER REGION
ユーザ領域
LEAD-IN REGION
リードイン領域
内周
INNER CIRCUMFERENCE
32
33
31
(a)ピット列
PIT STRING
(b)断面
CROSS SECTION
(c)RF 信号
RF SIGNAL
(d)TPP 信号
TPP SIGNAL

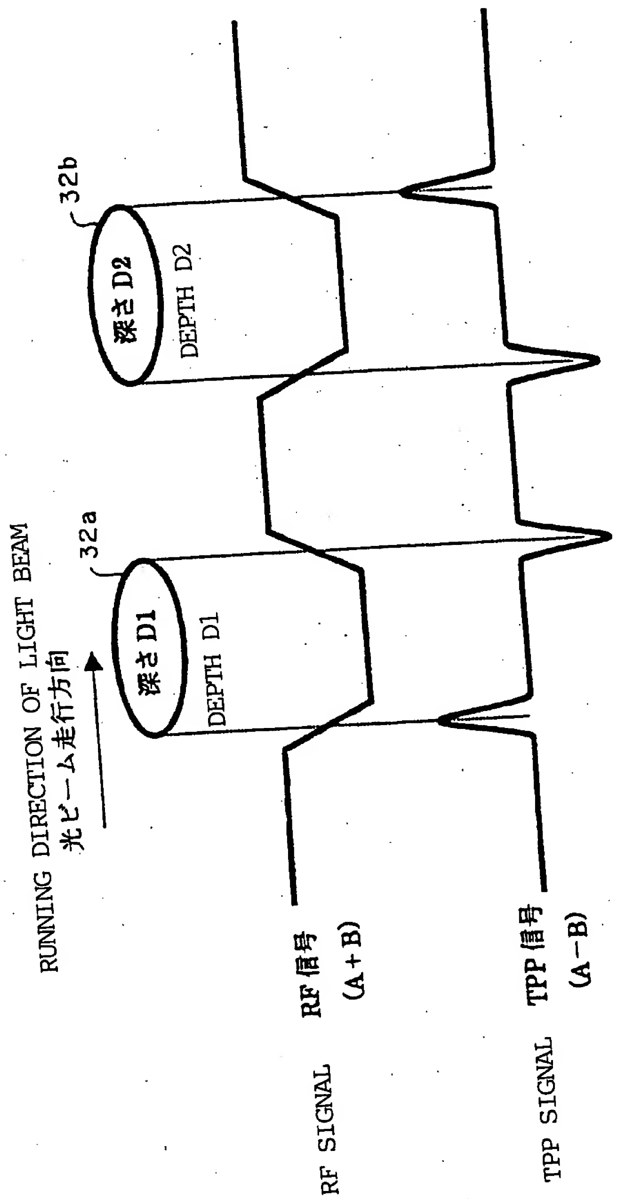
【図８】
Fig.. 8


(A)
RADIAL DIRECTION OF DISK
ディスク半径方向
RUNNING DIRECTION OF BEAM
ビーム走行方向
32
32
ピット
PIT
ピット
PIT
ピット
PIT
34
(B)
RUNNING DIRECTION OF BEAM
ビーム走行方向
RADIAL DIRECTION OF DISK
ディスク半径方向
B
A
37
35
36a
36b

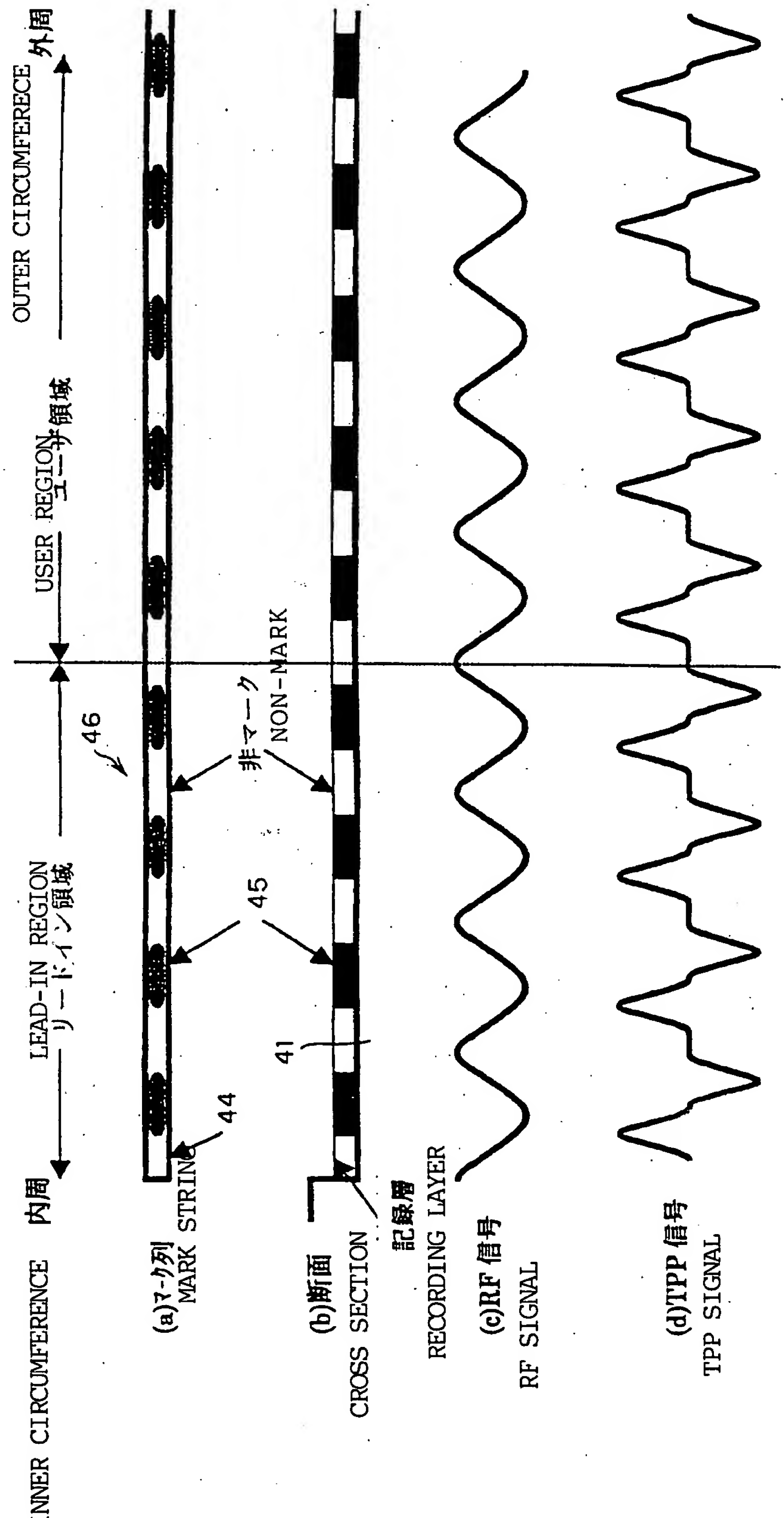
【図９】
Fig. 9


AMPLITUDE OF TANGENTIAL PUSH-PULL SIGNAL
タンジェンシャルプッシュプル信号振幅
RF信号振幅
AMPLITUDE OF RF SIGNAL
1
0.8
0.6
0.4
0.2
0
−0.2
−0.4
−0.6
−0.8
−1
D1
D2
λ/8n
λ/4n
3λ/8n
λ/2n
ピット深さ
PIT DEPTH
0
54
86
108
130
162
216
(nm)

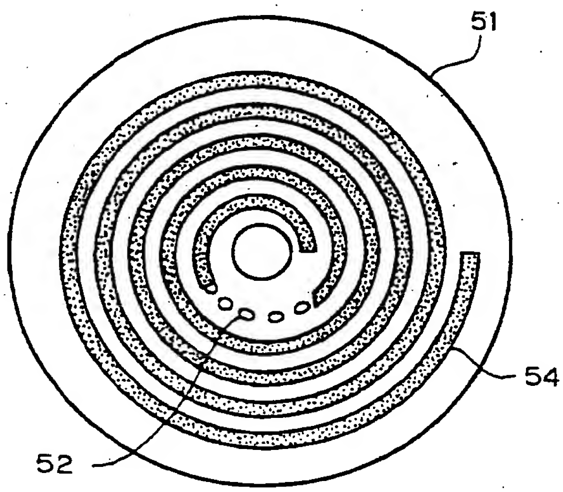
【図１０】
Fig. 10


RUNNING DIRECTION OF LIGHT BEAM
光ビーム走行方向
32b
深さ D2
DEPTH D2
32a
深さ D1
DEPTH D1
RF 信号
(A＋B)
TPP 信号
(A－B)
RF SIGNAL
TPP SIGNAL

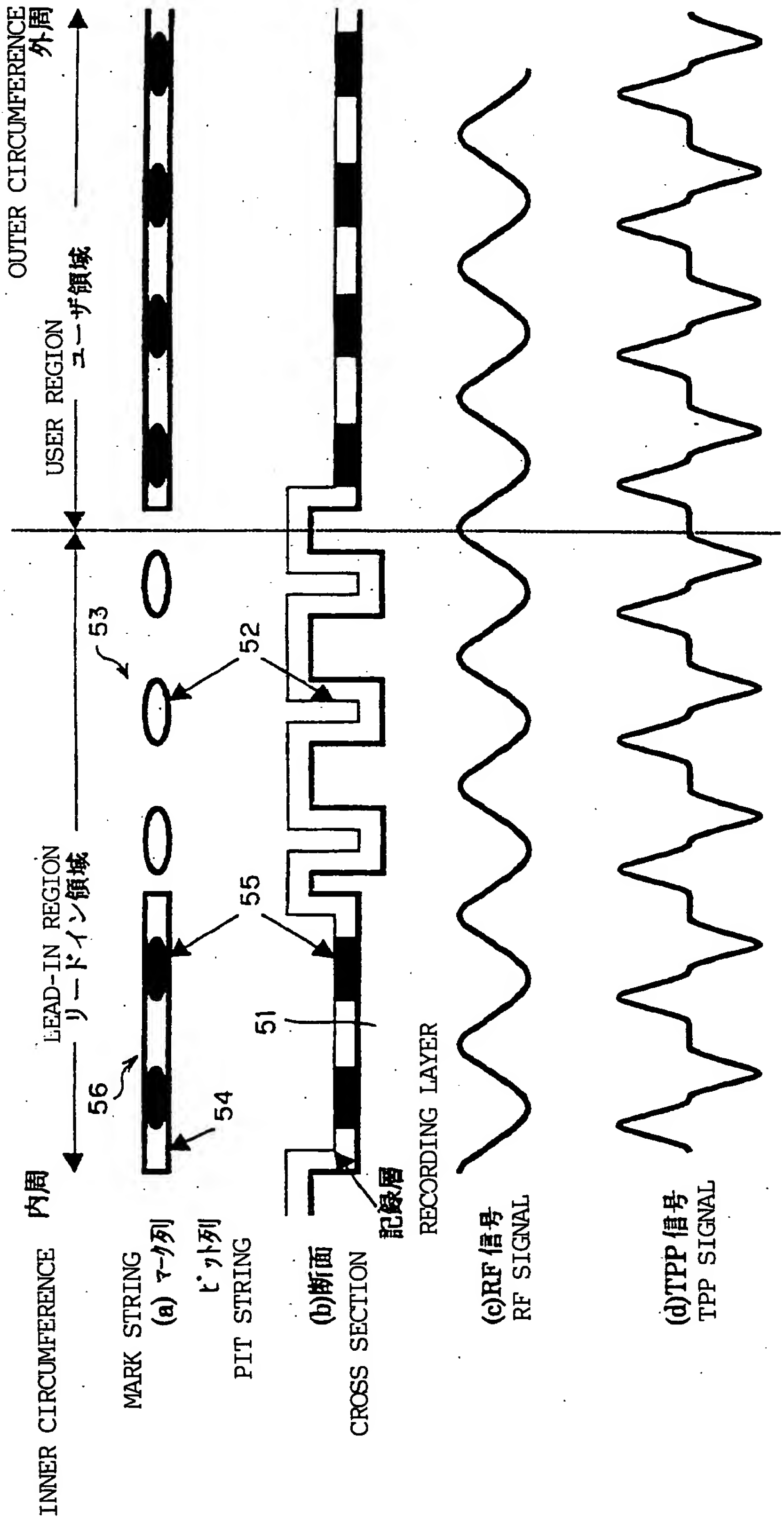
【図１１】
Fig. 11


外周
OUTER CIRCUMFERECE
ユーザ領域
USER REGION
リードイン領域
LEAD-IN REGION
内周
INNER CIRCUMFERENCE
46
非マーク
NON-MARK
45
41
44
(a)マーク列
MARK STRING
(b)断面
CROSS SECTION
記録層
RECORDING LAYER
(c)RF信号
RF SIGNAL
(d)TPP信号
TPP SIGNAL

【図１２】
Fig. 12



【図１３】
Fig. 13


INNER CIRCUMFERENCE 内周
OUTER CIRCUMFERENCE 外周
LEAD-IN REGION リードイン領域
USER REGION ユーザ領域
(a) ﾏｰｸ列 MARK STRING
ﾋﾟｯﾄ列 PIT STRING
(b)断面 CROSS SECTION
記録層 RECORDING LAYER
(c)RF信号 RF SIGNAL
(d)TPP信号 TPP SIGNAL
51
52
53
54
55
56

[Document Name] Abstract

[Abstract]

[Object] Provide a recordable optical disk and a reproduction apparatus thereof allowing increase of information in the lead-in without having to reduce the user region even when the amount of information in the lead-in is increased in an optical recording medium, and capable of copyright protection.

[Structure] A pit string 3 of the lead-in region in a disk includes a shallow pit 2a (depth D1) and a deep pit 2b (depth D2). The user region is formed of pit 2a of a constant depth. In reproducing pit string 3, an RF signal reflecting reduction in the quantity of reflected light at the pit portion, and a TPP signal (tangential push-pull signal) having different polarity reflecting the configuration of pits 2a and 2b of different depths are achieved. Reproduction of ternary recorded information based on the presence/absence and depth of pits 2a and 2b is allowed to significantly improve the recording density.

[Selected Drawing] Fig. 1